PB90-216367

Forest Response Program: National Research on Forest Decline and Air Pollution

(U.S.) Corvallis Environmental Research Lab., OR

1989

U.S. Department of Commerce
National Technical Information Service
NTIS

ERL-COR-902J

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/J-89/323	2.
3. RECIPIENT'S ACCESSION NO. PB 90 216367/AS	
4. TITLE AND SUBTITLE: The Forest Response Program: National research on forest decline and air pollution	5. REPORT DATE
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Paul Schroeder[1] and Ross Kiester[2]	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: [1]Northrop Services Inc., ERL-Corvallis; [2]US EPA, ERL-Corvallis, OR	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: US Environmental Protection Agency, Environmental Research Laboratory, 200 SW 35th Street, Corvallis, OR 97333	13. TYPE OF REPORT AND PERIOD COVERED: Journal Article
	14. SPONSORING AGENCY CODE: EPA/600/2

15. SUPPLEMENTARY NOTES

1989. Journal of Forestry 87(1):27-32.

16. ABSTRACT

The Forest Response Program (FRP) is a major research undertaking. It is fortunate to have the support of many of the nation's top scientists. The involvement of the Forest Service, the Environmental Protection Agency, and the broader scientific community gives the program a unique blend of perspectives and talents that is imperative to achieve the program's goal. A central challenge is to integrate results from fundamentally different kinds of research. Although the FRP will no longer exist in its present form after 1990, both the Forest Service and the Environmental Protection Agency are intent on continuing active acid rain research programs and expanding into important new areas. Two emerging issues are the effects of global climate change and of increased ultraviolet radiation resulting from stratospheric ozone depletion. The groundwork has been laid for close coordination of future research.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

18. DISTRIBUTION STATEMENT: Release to Public	19. SECURITY CLASS (This Report): Unclassified	21. NO. OF PAGES: 9
	20. SECURITY CLASS (This page): Unclassified	22. PRICE: A02

EPA Form 2220-1 (9-73)

PB90-216367

EPA/600/J-89/323

The Forest Response Program:

National Research on Forest Decline and Air Pollution

A central challenge is to integrate results from fundamentally different kinds of research.

The summers of 1987 and 1988 graphically demonstrated the importance the public places on its forest resources. Unusually arid weather severely parched western forests, making them dangerously dry. Lightning strikes came as they do every year, but the resulting fires were of historic proportions. Hundreds of thousands of acres of timber were consumed in California, Oregon, Wyoming, and other western states as the fires raged for weeks. The threat to our forests shared prime time with such other stories on network television news as the war in the Persian Gulf, nuclear arms control negotiations with the Soviet Union, and the presidential election campaign. The fate of our forest resources clearly is a major concern of the American public.

It follows that the perception of a potentially devastating and even more widespread threat to the nation's forests than fire would result in general public concern and alarm. That is just what happened earlier in the decade for acid rain. The dramatic, highly visible decline of forests in central Europe captured public attention; the theory that forest decline could be caused by acid rain or other air pollutants evoked

Paul Schroeder is forest scientist, NSI Technology Services, and A. Ross Kiester is mathematical statistician, Pacific Northwest Forest and Range Experiment Station, both with the U.S. Environmental Protection Agency Environmental Research Laboratory, Corvallis, OR. This article has been funded by the U.S. Environmental Protection Agency Environmental Research Laboratory. It is a product of the Synthesis and Integration Project of the joint U.S. Environmental Protection Agency and USDA Forest Service Forest Response Program.

NTIS is authorized to reproduce and sell this report. Permission for further reproduction must be obtained from the copyright owner.

By Paul Schroeder and A. Ross Kiester

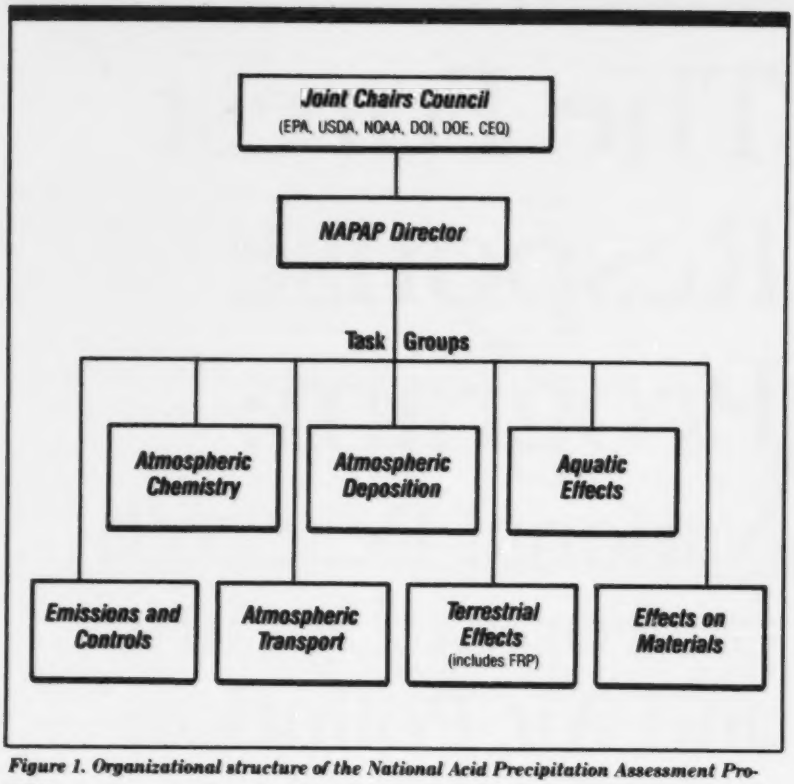

Figure 1. Organizational structure of the National Acid Precipitation Assessment Program.

public apprehension. Could the same thing happen in the United States? In response to this concern, Congress passed, and President Carter signed, the Acid Precipitation Act of 1980 (Title VII, Energy Security Act, P.L. 96-294), which eventually led to the establishment of the Forest Response Program (FRP) under the auspices of the National Acid Precipitation Assessment Program (NAPAP). Although formed at least partly in response to the European situation, the FRP began with no assumption of widespread forest decline in the United States and no presumptions on the role of air pollution.

NAPAP itself is an umbrella organization of 12 participating federal agencies (see box) with a current annual budget of approximately $85 million. NAPAP's goal has been to develop and progressively improve an objective and comprehensive information base for use by decision-makers. By working together, the participating agencies address national needs with an integrated and comprehensive program that avoids duplication and eliminates crucial gaps in the overall national effort.

NAPAP's work is carried out by seven task groups *(fig. 1)* that cover all aspects of acidic precipitation and its effects. The Terrestrial Effects Task Group is one of the largest and accounts for nearly 24 percent of NAPAP's annual budget. The FRP, part of this group, has a budget of approximately $16 million for fiscal year 1989, making it the largest component of the task group. This group is also involved in crop research.

The FRP is unusual among federal research programs in that it is truly an integrated interagency effort. The program is jointly funded and administered by the U.S. Environmental Protection Agency (EPA) and the USDA Forest Service. Both agencies have a direct interest in the effects of air pollution on forests: EPA from the regulatory perspective of protecting the nation's environment, and the Forest Service from the perspective of managing and husbanding the nation's forest resources. Since 1985, the two agencies have cooperated to plan the program's research direction and administer its implementation.

The FRP's Organization

The objective of the Forest Response Program is to provide information that can be used to address three broad questions related to environmental policy: (1) Is there a significant problem of forest damage in North America that might be caused by acidic deposition, alone or in combination with other pollutants? (2) What is the causal relationship between air pollutants and forest damage? (3) On a stand or regional basis, what is the dynamic relationship between air pollutants and forest damage?

To address these issues, the FRP must assess the present state of forest health, determine causes of changes in health, and if air pollution is a contributor, estimate the effects on forests of various levels of pollution. This information will be useful to EPA policymakers responsible for regulatory decisions and to those in the Forest Service involved in planning and forest management.

To make them more manageable, the

three policy questions have been defined by specific questions that are more readily addressed by program scientists. For example, the first policy question is subdivided into temporal and spatial questions. Are any observed changes in forest health greater than can be attributed to typical trends and variability? Is there a relationship between spatial patterns of forest health and those of pollutant exposure?

Different environmental conditions, forest types, species sensitivities, and pollution patterns imply that pollutant effects may vary around the country. To focus on problems most germane to specific areas, the FRP organized regional research cooperatives. Four cooperatives corresponding to major forest types or regions have been established: spruce-fir, southern commercial pine, eastern hardwoods, and western conifers *(fig. 2)*. Cooperative members are mainly university and government scientists whose research is funded by the cooperative. A cooperative manager and staff provide planning, administration, and technical direction. Participation by extramural scientists with diverse areas of expertise provides an interdisciplinary research approach.

The Atmospheric Exposure Cooperative and the National Vegetation Survey give additional research and support to the four regional cooperatives. The Atmospheric Exposure Cooperative monitors air quality at specific research sites and provides broader regional characterizations of air quality to the cooperatives. The primary contribution of the National Vegetation Survey is to estimate the extent and magnitude of forest decline in the United States.

Because of its size, diversity, and decentralized nature, the FRP faces a special challenge in maintaining a cohesive program. The Synthesis and Integration Project provides technical direction for the FRP and formulates answers to the policy questions driving the program.

Because the FRP results will influence decisions on regulation of pollutant emissions, research and data must be of the highest quality, and full documentation of procedures and results must provide a defensible stance in any controversy. The Quality Assurance Project promotes and assures collection of top-caliber data. It also provides guidelines for comparability of data among projects, documents research procedures, and provides qualitative and quantitative evidence of data reliability.

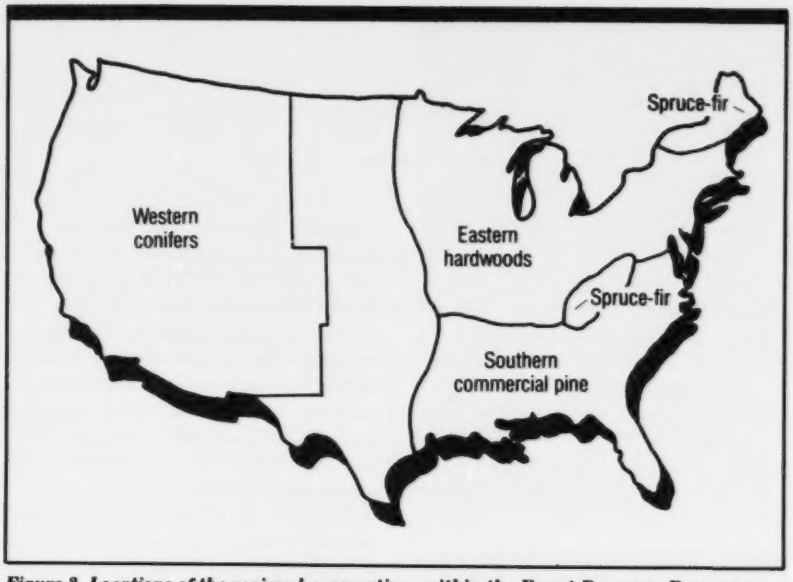

Figure 2. Locations of the regional cooperatives within the Forest Response Program.

Research Approaches

The FRP takes two major approaches to research: epidemiology/field ecology and physiology. The epidemiology/field ecology approach is characterized by broad surveys of forest health and a search for spatial or temporal patterns that may be related to environmental patterns such as air quality and atmospheric deposition. This is the primary direction taken to address the first policy question. Analyses of historic data, such as investigations of tree ring records, are also important in this approach.

The physiological approach concentrates on the effects of pollutants and other environmental stresses on the health of individual trees. This approach is the program's main vehicle for addressing the policy question of cause and effect. Studies include intensive field classification studies and controlled and manipulative laboratory, greenhouse, and field experiments using combinations of pollutants.

NAPAP Member Agencies

Council of Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Health and Human Services
Department of State
Department of the Interior
Environmental Protection Agency
National Aeronautics and Space Administration
National Oceanic and Atmospheric Administration
National Science Foundation
Tennessee Valley Authority

Components of the Forest Response Program

Spruce-Fir Research Cooperative
Southern Commercial Forest Research Cooperative
Eastern Hardwoods Research Cooperative
Western Conifers Research Cooperative
Atmospheric Exposure Cooperative
National Vegetation Survey
Synthesis and Integration Project
Quality Assurance Project

Results from the two research approaches are coordinated to quantify and project the effects of pollutants on forest growth and thereby address the remaining policy question. Integration and unification are achieved by focusing on the biological levels of organization: seedling, branch, tree, stand, and region. The levels are linked with statistical techniques and mathematical and computer simulation modeling.

Epidemiology/field ecology. Forests naturally change over time. A decline is a negative trend beyond the natural bounds of variability. Four major sources of data are being analyzed to study trends and their natural variability and to identify and estimate the extent and magnitude of any current forest decline.

Dendrochronological (tree ring) studies provide data on historical forest growth trends. Tree ring studies are now under way on the northern and southern ranges of red spruce, on ponderosa pine in Arizona and California, and on Douglas-fir in the Pacific Northwest.

The Forest Service Forest Inventory and Analysis (FIA) program has extensive survey data that date back several decades in some parts of the country. FIA data formed the basis for concerns about recent growth declines among southern pine species. More intensive evaluations of FIA data in the southeastern United States continue to document a growth decline in natural stands of loblolly and shortleaf pine in the Piedmont region of Georgia and the Carolinas. No clear or direct link between regional air pollution levels and growth patterns has been demonstrated.

A third source of data for the epidemiological studies is the remeasurement of fixed plots. Fixed-plot remeasurement studies are carried out primarily in the South to complement the FIA analyses. FIA data are valuable because of their extent, but they were never intended to be used to characterize forest growth patterns or to estimate changes in growth. They are simply an inventory of regional stocking levels at single points in time. The more sophisticated analyses that can be performed on fixed-plot data in conjunction with FIA analyses will provide a more dependable picture of southern pine growth trends.

The FRP is also conducting studies searching for distinctive spatial patterns of forest health and condition that are related to spatial patterns of atmospheric deposition. Current work is being done in Pennsylvania, an area over Michigan and Minnesota, the Ohio Valley, the southern Great Lakes, the Puget Sound area, and the Appalachian Mountains. Tree ring, FIA, and remeasurement studies can provide information about forest growth rates and warn us if something unusual is happening, but they cannot link growth trends to air pollutants or other suspected causes. Spatial studies may be able to demonstrate correlative links if they exist.

Physiology. To go beyond simple correlation and investigate the possible causal role of air pollutants in growth declines requires carefully designed experiments. A large portion of the FRP research examines the growth and physiological responses of tree seedlings to controlled exposures of air pollutants. Program scientists use growth chambers, continuously stirred tank reactors, and open-top chambers to conduct their experiments. Treatments include gaseous sulfur and nitrogen compounds, ozone, simulated acid rain over a range of pH values, simulated acid mist, and hydrogen peroxide. Other environmental factors such as drought stress are sometimes included. Because these experiments are generally conducted over several years, results are only now becoming available.

Another type of experimentation employed by the FRP is the branch chamber exposure system. This work is needed to understand how fully grown, mature trees respond to exposure to pollutants. Enclosure chambers allow carefully controlled doses of pollutants to be applied to intact branches with several age classes of needles. This ap-

proach enables FRP scientists to experiment directly on mature trees, but is less expensive and technically simpler than working with whole trees.

The FRP also interacts with other research programs that conduct more intensive ecosystem-level studies in the field to provide a broader picture of pollutant effects. These types of projects are especially valuable for assessing effects on nutrient cycling and levels of soil nutrients available for plant uptake. Because these are dynamic processes, studying them requires a systems-level perspective. This complex research is also expensive and time consuming; it is more than the FRP can adequately handle on its own. Collaboration with others is a useful strategy to enable the program to make a meaningful contribution to ecosystem studies and to benefit directly from other research. Some FRP projects, for example, are coordinated with the Electric Power Research Institute's Integrated Forest Study.

Synthesis and Integration

A central challenge for the FRP is to integrate results from fundamentally different kinds of research. How can information be pulled together in a cohesive way to address the program's policy questions? To answer this challenge, the FRP adopted a previously untried approach based on biological levels of organization: seedling, branch, tree, stand, region. There are two reasons for using this approach. First, each level can be studied and analyzed by itself. Second, information at one level can be synthesized and used as input to the next higher level. The levels and methods by which they are linked are shown in *figure 3*. One advantage of this modular approach is that it provides a framework that can accommodate and assimilate results both from survey (epidemiology/field ecology) and experimental (physiology) research.

As *figure 3* illustrates, one way that information is integrated within the FRP is through computer simulation models. These may apply to a single level of organization or may link two levels. For example, for obvious practical reasons much of the experimental work in the program is conducted on seedlings. It is important, however, to make the connection between seedling physiology and mature tree physiology. Although this is difficult and success is not guaranteed, models can help. In this case, the program uses physiological process models to make the seedling–mature tree integration. Focusing on basic processes rather than simply focusing on growth response to exposure should make some of the seedling results applicable to mature trees also.

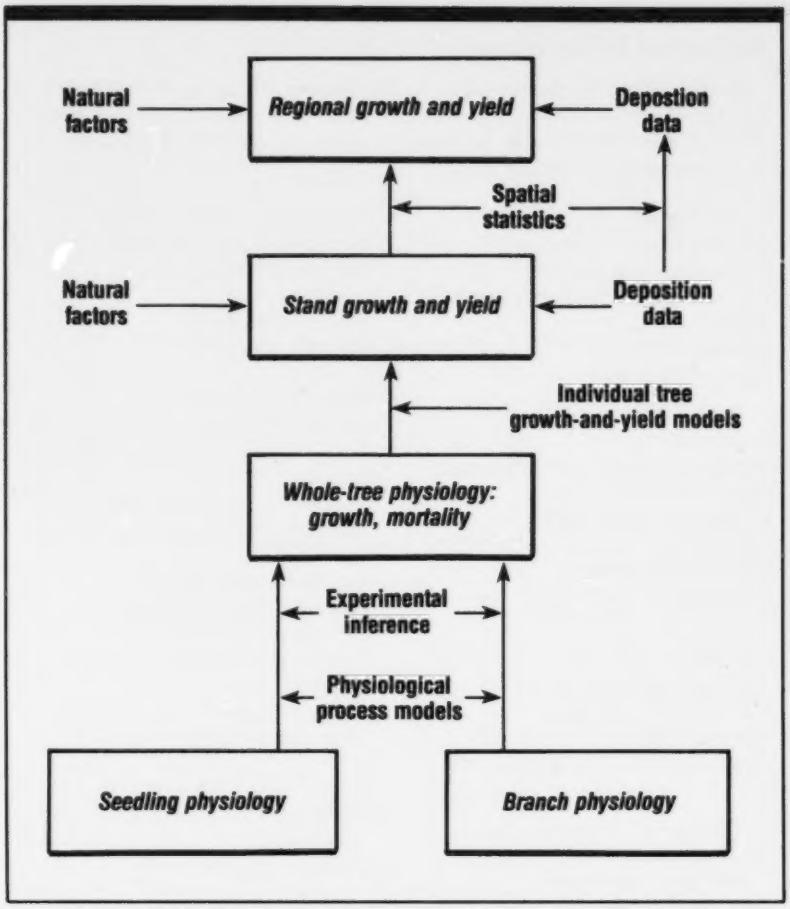

Figure 3. Biological levels of organization and linkage methods for research in the Forest Response Program.

Figure 3 also illustrates the parallel use of branch studies in developing an understanding of mature tree response. Branch studies contribute to process-level models and can help to improve the interpretation of seedling results.

At the stand level, a modular system of simulation models will be used. A se-

Additional Information

This article broadly describes the Forest Response Program. More detailed information on the national program, the research cooperatives, the Synthesis and Integration Project, and the Quality Assurance Project can be obtained by contacting the following persons:

Gerard Hertel
National Program Manager
Forest Response Program
Northeastern Forest Experiment Station
370 Reed Road
Broomall, PA 19008

Roger Blair
Deputy National Program Manager
Forest Response Program
Environmental Research Laboratory
200 S.W. 35th Street
Corvallis, OR 97333

Joe Barnard, Director
National Vegetation Survey
USDA Forest Service
P.O. Box 12254
Research Triangle Park, NC 27709

Ann Bartuska, Director
Southern Commercial Forest Research Cooperative
1509 Varsity Drive
Raleigh, NC 27606

Chris Eagar, Technical Coordinator
Spruce-Fir Research Cooperative
Northeastern Forest Experiment Station
370 Reed Road
Broomall, PA 19008

Ross Kiester, Project Leader
Synthesis and Integration Project
Environmental Research Laboratory
200 S.W. 35th Street
Corvallis, OR 97333

Barry Martin, Director
Atmospheric Exposure Cooperative
Environmental Protection Agency
MD-44
Highway 54 and Alexandria Drive
Research Triangle Park, NC 27711

Max McFadden, Director
Eastern Hardwoods Research Cooperative
Northeastern Forest Experiment Station
370 Reed Road
Broomall, PA 19008

Richard Olson, Director
Western Conifers Research Cooperative
Environmental Research Laboratory
200 S.W. 35th Street
Corvallis, OR 97333

Jack Winjum, Project Leader
Quality Assurance Project
Environmental Research Laboratory
200 S.W. 35th Street
Corvallis, OR 97333

ries of individual tree-based stand models will be constructed whereby individual trees are described, perhaps by the physiological process models, and then the models will interact to produce patterns of stand dynamics. This approach allows the incorporation of physiological mechanistic information in specifying or describing individual trees. It also recognizes that a stand is not simply the sum of its individual parts but the result of many complex interactions between individual trees and the environment. Natural factors such as drought, nutrient balance, or pest and pathogen interaction can also be included. Once these stand models are established, they can be used in conjunction with spatial statistical techniques to undertake the appropriate regional aggregations.

This hierarchical or scaling-up approach is not without potential pitfalls and uncertainties. Seedlings are not the same as mature trees. There are crucial differences that affect their responses to air pollutants and other stresses. These include differences in the ratio of photosynthetic to respiring tissue, canopy microclimate, leaf morphology, and water and nutrient regimes. We also know that individual tree effects can be either compensated for or magnified at the stand level. Despite these differences, the strategy outlined above is a feasible one if the obstacles are recognized and accounted for as much as possible.

The Future

By any standard, the Forest Response Program is a major research undertaking. It is fortunate to have the support of many of the nation's top scientists. The involvement of the Forest Service, the Environmental Protection Agency, and the broader scientific community gives the program a unique blend of perspectives and talents that is imperative to achieve the program's goal.

When NAPAP was established in 1980, it was given a 10-year lifespan. That means the FRP is also due to draw to a close. Clearly, though, environmental issues related to forest resources are growing, not diminishing. Although the FRP will no longer exist in its present form after 1990, both the Forest Service and EPA are intent on continuing active acid rain research programs and expanding into important new areas. Two emerging issues are the effects of global climate change and of increased ultraviolet radiation resulting from stratospheric ozone depletion. The working relationship established between the two agencies through the FRP should continue even after NAPAP formally ends. The groundwork has been laid for close coordination of future research. ■

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This article documents research that was conducted under the auspices of the U.S. Environmental Protection Agency (USEPA). As an arm of the government, the USEPA has a paid up, non-exclusive, irrevocable, worldwide license to reproduce, prepare derivative works, and distribute to the public all of the material contained herein, and to grant others acting on its behalf the right to do so. The USEPA grants to the National Technical Information Service, Department of Commerce, the right to act as its agent in the distribution of this material.